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PETROLOGY, STRUCTURAL AND MINERALOGY OF THE PRECAMBRIAN ROCKS AROUND OKEMESI-IJERO AREA, SOUTHWESTERN NIGERIA

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ABSTRACT

Petrological, structural and mineralogical structural studies of the area around Okemesi-Ijero were carried out using geological field mapping and petrographic analysis of the rocks for its mineral composition. Rock types such as quartz-biotite-schists, banded-gneiss, granite-gneiss, biotite-gneiss, calc-gneiss, porphyritic granites, charnockites, massive and schistose quartzites and mica schists. Structural assessment of the rocks revealed folds, fractures, faults and veins as product of Precambrian deformations. The rose plots showed fractures on the granites are more intersected and long, while those on the quartzites are shorter. Other lithologies such as schists, gneisses and migmatites have very few fractures because of their ductile nature. Petrographic studies of the rocks revealed the modal composition of minerals in the rocks such as quartz (>70%), albite (22%), microcline (30%), muscovite (26%), plagioclase feldspar (5-15%) and hornblende (4-5%). However, mineralization in the studied area is structurally controlled by the folds, fractures, faults and veins which provided the structural framework for epigenetic mineralization in the studied area.

KEYWORDS: Okemesi-Ijero; Lithologic Units; Rose Plots; Photomicrographs; Minerals

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Original Article

INTRODUCTION

The Precambrian rocks around Okemesi-Ijero area and its environs, Southwestern Nigeria is one of the three major litho-petrological components that make up the geology of Nigeria. The Nigerian basement complex forms part of the Pan-African mobile belt and lies between the West African and Congo craton and south of Tuareg shield (Black, 1980). The Nigerian basement complex was affected by the 600Ma Pan African orogeny and occupies the reactivated region which resulted from plate collision between the passive continental margin of the West African craton and the active Pharusian continental margin (Dada,2006;Burke and Dewey, 1972). The rocks in the studied area had undergone polycyclic deformation thereby causing the formation of both micro and macro structures in them such as foliations, folds, microfaults, joints, quartz veins, fractures, veinlets, solution holes etc. these structures are observed to be the main factor controlling the drainage pattern in the area. The major fold situated a few kilometers north of Okemesi township is a NNE-SSW trending antiformal structure which was formed during the deformational phase of the Pan-African orogeny (Odeyemi, 1993). Generally, these structures are obviously the manifestation of Precambrian deformation which obliterated most of the earlier structures. Several literatures abound which includesAkintola*et al.*,(2013) carried out the petrography and stream sediment geochemistry of Ede and its environs in order to identify the rock units with their mineralogical appraisal and to determine the concentration and distribution of major and trace elements in the stream sediments with a view to elucidate the mineral potentials of the study area. Ademeso*et al.*, (2013) concluded that the rocks of Ife-Ilesa schist belt were affected by two episodes of high pressure metamorphism and experienced an episode chemical

reconstruction and cataclastic metamorphism by extension by parts and can therefore be classified as mylonites. Olaolorun and Oyinloye, 2010; Oyinloye, 1997; Rahaman*et al*,(1988) and according to Oyinloye and Adebayo (2005), the migmatite-gneiss complex in Ijero area is composed of a mafic portion made up of biotite, hornblende, quartz and opaque minerals, while the felsic portion is qartzo-feldsparthic. Other rocks identified by these authors are charnockites, metasediments composed of amphibolite schist, mica-schist and quartzites.Some work has been done in terms of structural mapping of the area. Also a few workers have carried out analysis of remote sensing data of parts of the area. Ayodele (2010a) carried out a remote sensing evaluation and geological studies of Okemesi area, Southwestern Nigeria by analyzing and interpreting a LANDSAT^{TM} imagery covering the entire area, followed by minimum ground thruth. He extracted a total of 260 lineaments from the different rock units that underlie the study area. Also, fold and fractures including faults were detected on the imagery, and the rocks bear imprints of different generations of folding. Ground thruth confirmed the presence of overturned antiformal and asymmetric folds, the faults seen on ground were attributed to fractures that occurred during the folding episodes in the area. Anifowose and Borode (2007) studied the photogeology of the fold structure in Okemesi area and indicated the existence of isoclinal limbs of a megafold in association with other minor folds and subsequent fracturing resulting in the plunging of the fold generally towards the north and the south. Anifowose*et al.*,(2006) also noted that joints ranging from minor to major ones are found in all rock types, some of which are filled with quartz, feldspar or a combination of both. They lie generally in the NE-SW directions. Caby and Boesse (2001) interpreted the Petro-structural data of Ife/Ilesha Schist belt and reported the existence of thrust tectonics in the Nigeria basement complex. In particular, Boesse*et al.* (1989), Caby and Boesse (2001) have inferred and describe the presence of nappes from the shallow dips of foliations and shear zone, low angle thrusts and associated recumbent folds in the Ife-Ilesha area.Caby and Boesse (2001) interpreted the Petro-structural data of Ife/Ilesha Schist belt and reported the existence of thrust tectonics in the Nigeria basement complex. Also, all the foliations exhibited by rocks of south-western Nigeria excluding the intrusives are tectonic in origin because pre-existing primary structures have been obliterated by subsequent deformations (Odeyemi*et al.*, 1999). The general north-south trend of major fractures and foliations within the basement complex is as a result of deformation. Odeyemi (1992) carried out remote sensing analysis of the region around Ifewara fault using remotely sensed images, and concluded that combinations of transcurrent and dip slip movements may have taken place along the fault at various times. However, this research is aimed at unravelingthe geologic, structural setting and associated minerals inherent in the rocks in relation to geodesy.

Location and Accessibility

The study area lies within latitudes 7^0 45'N and 8^0 00'N and longitudes 4^0 52'E and 5^0 08'E which covers part of Ekiti and Osun, southwestern Nigeria, with a total surface area of 821.4km^2 (Figure 1). Major towns in the area include Okemesi and IjeroEkiti. Other towns include Epe, Ikoro, Effon, Ipoti, odo-owa, Ayegunle, while those in Osun State are Oke-ila, Ilupeju, Edemode, Orangun and Oba-sinkin .The areas which fell within Osun, Southwestern Nigeria can be rated moderately motorable due to interconnectivity of roads, while areas within Ekiti can be rated poor because there are only minor roads and footpaths which are not motorable. Localities within Ekiti are mainly small villages with linear settlement along the road, while nucleated settlement predominates in Osun. The study area is generally accessible through network of all seasonal roads and motorable tracks which links it with other part of the country. Similarly, villages and towns have major and minor roads and also footpaths which are inter-linked to one another (Figure 2).

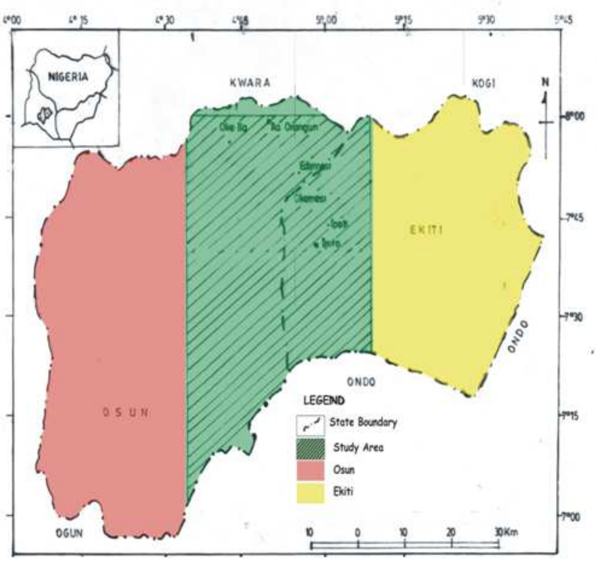

Figure 1: Map of Osun and Ekiti, Southwestern Nigeria Showing the Study Area (Inset: Map of Nigeria Showing Osun and Ekiti States)

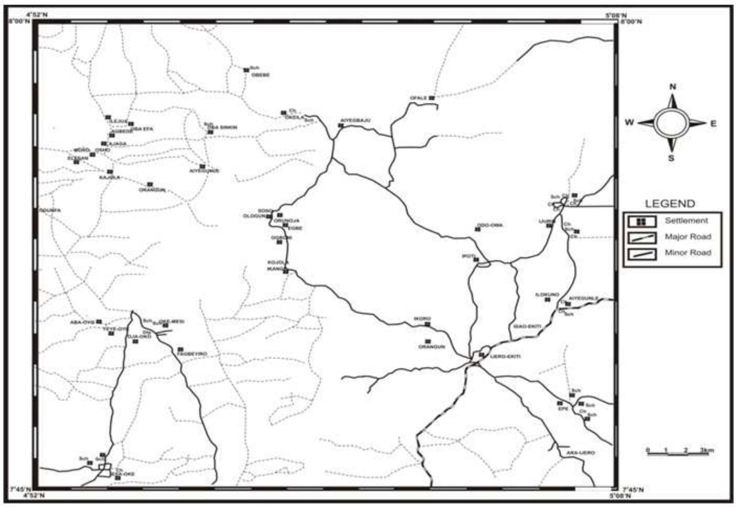

Figure 2: Interconnectivity Map of the Study Area Geology of the Study Area

Geology of the Study Area

The study area is underlain by crystalline rocks of Precambrian basement complex of southwestern Nigeria, which is also part of the basement complex rocks of Nigeria. The study area is also part of the regional Dahomeyide fold belt defined by Affaton et al. (1991), (Figure 3)) and so it is not an exception to the structural and deformational episodes that pervaded Nigeria's Precambrian basement complex. Within the basement complex, tectonic deformation has completely obliterated primary structures (Oluyide, 1988) except in a few places where they survived deformation (Okonkwo, 1992). The Ifewara fracture zone separates the rock of Ilesha schist belt into two structural units of contrasting lithologies (Hubbard, 1975; Ako*et al.*, 1978, Folami, 1992; Odeyemi, 1993). Other workers (Klemm et al., 1984; Wright*et al., 1985*; Oyinloye and Odeyemi, 2001; Anifowose, 2004) have provided evidences in support of the existence of the structure as well as its significance in terms of tectonic movements. Also, sutures have been proposed along the two transcurrent fault zones, and in particular within the Ife-Ilesha schist belt, which has been interpreted as a back-arc marginal basin (Rahaman*et al.*, 1988), and east-verging nappes (Caby&Boesse, 2001). It is worthy of note that the Ilesha schist belt

hitherto thought to be devoid of iron ore deposits has been reported to host some deposits of “banded iron formation” (Elueze,2000).The dominant rock type in the study area is the quartzites of the EffonPsammite Formation which occurs mostly as massive quartzites, schistose quartzites and quartz schists. The EffonPsammite Formation which extends to Okemesi (Hubbard, 1966; De Swardt, 1953; Dempster, 1967) is a belt of quartzites, quartz schist and granulites which occurs largely east of Ilesha and runs for nearly 180km in a general NNE-SSW direction. The various lithologic descriptions of the different rocks mapped in the studied area are discussed below.

Banded Gneisses

This lithology covers the southwestern part of the study area around Okokoro, Aba Francis and Aba-Ori-Apata near IkoroEkiti. Texturally, they are medium to coarse grained with alternating bands of light and dark coloured portions of about 3cm thickness with complete gradation between them. They occur as low lying outcrops which have been intruded by pegmatite in the south eastern corner of the area. The rock consists of alternating felsic and mafic minerals and structures like banding, microfolds and fractures were noticed on the outcrop.

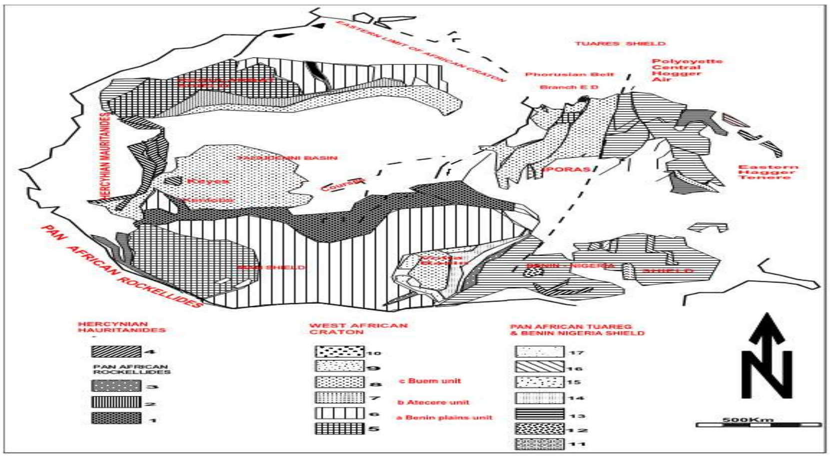

Figure 3: The West African Craton and Surrounding Orogenic Belts (Affaton, 1991)

They have whitish grey tones. The samples mapped around Okemesi and Ipoti are medium to coarse grained and are foliated and display compositional banding of the mafic and felsic minerals. The rock strikes at 333^0 and dips at 60^0W.The mineralogy consist of quartz, biotite and orthoclase and microcline feldspars.

Quartzites

These tend to form good topographical features which rise up to about 400metres above the surrounding terrains forming ridges. Quartzites cover the northern part around Oke-Ila, Ilupeju areas to central, western (Ayegunle), extending to the southwestern and southern parts of Okemesi (Ajindo) of the study area. Around the study area, the varieties of quartzite encountered are massive, milky, smoky, sugary, ferrugineous and schistose quartzites. However, schistose, ferrugineous and smoky varieties are the commonest in Okemesi area. The massive quartzites are not foliated but hard and are compact, the schistose quartzites are foliated and exhibit alternations of felsic mineral such as quartz and mafic mineral such as biotite with planar fabric. The milky ones have milky appearance by inspection and developed slickenside surfacesn with specks of muscovite. The smoky ones are formed by different oxidation states of iron in the crystal lattices of the rock or due to impregnations of some transition elements during the rock formation. The sugary ones have granular textures and are friable when struck with hammer.The ferruginous types are rich in iron.They are very common in Okemesi

and itawure.Thequartzites have varying textures from equigranular, medium grained to coarse-grained. The varieties of quartzites are closely related that, often, it is impossible to indicate them as separate units on the map. The quartzites consist of mainly quartz which is usually more than 70% with minor amounts of interlocking grains of biotite and orthoclase. Structurally, the quartzites are jointed, with some having joint sets around Ayikunnugba (Oke-Ila) area, while others are foliated. Dips ranging between 40^0W-66^0 W were measured around Soso and OkoAjindo areas. In some areas for instance, they have very high dips ranging from 66^0 E to almost horizontal at Okemesi, most especially along the limbs and fold closure. The quartzites in the area have orange-yellow colour due to mineral impurities.Quartz vein is the dominant structural feature on the rocks in this locality.

Biotite-Gneisses

This is a foliated, medium to coarse-grained, dark to almost black coloured rock composed chiefly of biotite and little quartz. It occupies the north central area and extends towards the north western part of the study area. A band of biotite gneiss concordantly lies within the quartzites around Ajindo area. The rock has been severely weathered and covered with sand thereby making field observation difficult to carry out. The varieties seen at Ikoro and Ijero are the highly foliated type with bands of black tints imposed by biotite impregnations alongside felsic minerals such as quartz and plagioclase feldspar. Most of the mineral alignments are conformable with the foliation planes of the adjacent schistose rock.

Granite-Gneiss

The granite gneisses are common in Okemesi and Epe. They exhibit mineralogical banding of felsic and mafic minerals. The felsic minerals are the quartz and feldspar (plagioclase) and mafic minerals are biotite. The texture is medium to coarse grained.

Biotite -Schists

The biotiteschists encountered in the study area occurs around ArapateErigbe and Soso area of EkitiState as a lenticular body within the quartzites and migmatite gneiss, and it is exposed due to stream activity as low lying outcrop. It has undergone various levels of deformation. Structurally, foliation is present thereby making the name “biotite schist” appended to the rock as confirmed by petrographic studies. Other structural features on the rock include microfolds and joints which control the stream flow. Field observations showed that this rock dips at 48^0 W to the surrounding rocks. The rock is medium grained and contains quartz and biotite which is the dominant mineral, and it is dark grey in colour. The rock also occurs in Ikoro and Ijero area as a schistose rock with grayish colour, and with black patches of biotite, It exhibits fine grained texture. It covers nearly two-thirds of Ijero area with pegmatite intrusions along Ijero-Ikoro road. It is also found in Arapate/Soso area with structures such as foliations and micofolds. Mineralogically, it contains quartz and biotite.

Quartz-Biotiteschists

This group of rock occurs in lowland areas between quartzite and banded gneiss around Oko-Esinkin2 area (eastern part of Okemesi) where it has been exposed by stream channel and road cut. The rock has been highly deformed with the adjacent migmatite-gneiss- quartzite complex, the foliations on the outcrop is defined by biotite streaks. The rock has medium to coarse grained texture and consist mainly of biotite, quartz, plagioclase feldspar and orthoclase feldspar. Structures found on the outcrop are fractures, and the rock is grey to dark in colour.

Pegmatites

This lithologic unit ranges from a few meters in length and is located in the southeastern part of Okemesi where it intrudes the banded gneiss around Aba Francis and Ikoro area as an isolated hill. Texturally, it is extremely coarse-grained with quartz, feldspar and muscovite as distinguished mineral component. Quartz vein, joints and veinlets are the structures observed on the outcrop. Based on field observation, the pegmatite is the complex type with distinct textural and mineralogical variations with an impure white colouration. It is the youngest rock in Ikoro area, unlike the Okemesi pegmatite which is the simple type due to uniform variation of its constituent minerals. Pegmatite intrusions also occur towards the south-western part very close to the centre of Ijero town, which is also complex. It extended to the quarry site in Ijero along Ijero- Ipoti road. The pegmatite in Ijero area is zoned, consisting of massive quartz at the core, and followed by mica schists with smoky quartz impregnated with tourmaline and purplish quartzite. In Ara and Epe area of Ijero, the pegmatites here intruded into the biotite schist and migmatite gneiss that occupies the central part of the area, covering about three-quarter of the total land mass. The pegmatites in this area are very coarse grained igneous type with phenocrysts over 250mm in length, usually of granitic composition. The pegmatite in Ipoti and OdoOwa areas are associated with cassiterite-tantalite mineralization (Fadipe, 1988). They are found associated with migmatite gneiss and amphibolites with very coarse grained texture and consists of feldspar, tourmaline and garnet while pegmatites in Ijero is enriched with unusual trace elements which thus result in the crystallization of unsual rare minerals such as beryl, tourmaline, columbite and tantalite. The pegmatites in Ijero occur as a low but large elongate hill of average height of about 50m above sea level. Some of the pegmatites in Ijero have been and are still being worked on most especially at Ijero and other villages such as Ikoro, Odo-Owa, Saloro and OkeAsa. The dominant minerals are orthoclase, albite, quartz, microcline and biotite

Calc-Gneiss

This is a typical gneissic rock with abundance of calcium. It exhibits a characteristic black colour with white fragments of quartz. The texture of the rock is mostly fine grained. Joints are the major structures discovered on the outcrop, and are common in most parts of Ikoro. Part of the lithological unit is exposed at Odoagba (Ikoro) where the stream takes it course. They are medium to coarse grained.It is also common in Ijero where it is composed chiefly of calcite and quartz. It occurs mainly as nodules and discontinuous streaks up to four inches in thickness. It is also made up of a mosaic of twinned grains of calcite enclosing isolated rounded crystals or composite spots of silicate minerals.

Granites

Varieties of granites based on mineral composition, texture and grain sizes are very prominent in the south eastern part of the study area most especially in Ofale, Osun/ Epe, Iroko, and Idao parts of the study area and form well defined boundaries with the quartzites. Their textures range from fine, medium to coarse grained. They occur as hilly, low lying, flat and extensive outcrops in most area with sparse vegetations. Structures common the outcrops include quartz vein, veinlets, pegmatite dykes which trend north-south, exfoliation, folds of different styles, xenoliths etc. A typical granitic rock must have > 60% of quartz to be termed an acid igneous rock. However, the granites occur as pockets of rocks within the biotite gneiss in Ikoro and Ijero area. They have colour variations ranging from specks of whitish, grayish to ash colour and patches of dark colour indicating ferromagnesian minerals.

Mica Schists

The mica schists extend across most part of Ipoti, OdoOwa and Ijero, but occur prominently around Ipoti and Ijero. They are highly susceptible to weathering and erosion thereby reducing the quantity of fresh samples. In these areas, quartz-muscovite and quartz-muscovite-biotite schist are exposed in many places and have been highly pegmatized. The quartz biotite schist found in the area could be due to boron metasomatism traceable to tourmaline at OdoOwa where they are relatively well exposed.

Migmatite-Gneiss Complex

This is presumably the oldest group of rocks and the most wide spread of all the lithologies, occupying 30% of the total surface area of Ijero and its surroundings. Its concordant lithostratigraphic relationship with the juxtaposed quartzite at Ayegunle gives credence to its probable metasedimentary origin. It is a mixed rock with a characteristic nature of a typical metamorphic rock which has taken an igneous character through partial melting. The migmatite has a mineralogical composition of quartz, orthoclase feldspar, hornblende and mica.. It is not widely distributed in AraEpe area unlike the pegmatites, but occupies the northern part. It is characterized mostly by alternating light and dark bands of minerals. In Ipoti, OdoOwa area, the rock has been weathered in-situ to give rise to high quality clays of economic importance, whereas, it occurred as a fresh low-lying outcrop in Ijero. It also possesses schlieren texture which is an example of granite formation in migmatites. This is typical of the samples picked from Epe. Migmatites in Epe are characterized by ptygmatic folds and are believed to exhibit ductile deformation of the gneissic banding. Structures like folds and microfaults were also seen on the outcrop. The strike value of the rock is 340^0 and dip is 32^0W.

Charnockites

The charnockites occur as an intrusive body north of OdoOwa within the massive quartzites and the gneisses as a coarse grained variety of charnockites which are foliated. They vary in texture and petrography and range from banded types to fine and medium grained. Though, the coarse grained varieties are common around Ipoti and Odoowa area. They also occur as discrete and individual bodies within the migmatite-gneiss-quartzite complex. Mineralogically, it consists of hornblende, biotite with little or no quartz. Structures seen on the rock are solution holes, quartz veins. The various rock units mapped in the course of field work were compiled to produce a geologic and cross-section map of the study area Figure .4.

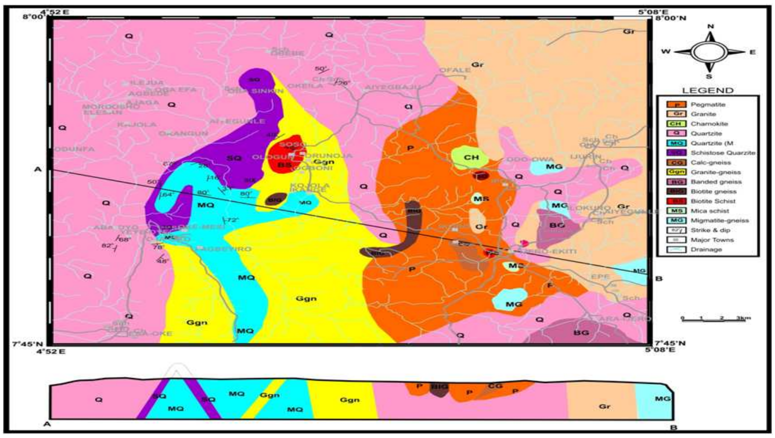

Figure 4: Geological Map of the Study Area

Method of Study

The geological mapping was carried out at a scale of 1:50,000 using grid-controlled sampling method at a sampling density of one sample per $4sqkm^2$ for the collection of rock samples (Figures 3&4). Thirty-five (35) rock samples were obtained. The rock samples were collected from different localities in the studied area, after which they were labeled accordingly to avoid mix up. The location of each outcrop was determined with the aid of a Global Positioning Systems (GPS) and the lithologic and field description of each samples were correctly recorded in the field notebook. The fresh and well labeled rock samples collected were brought to the Petrological Laboratory at the Federal University of Technology (FUTA), Akure for the thin section preparation. Cutting machine was used to cut the samples into desired sizes of glass slides, the cut specimen was lapped on a lapping machine and silicon carbide was put on the lapping glass which was put on the lapping table with some water and it was lapped on the glass until the surface was very smooth. After lapping, the sample were moved to the thermoplate and the lapped specimen was washed with water and put on a thermoplate which is regulated to 102^0C for about one hour to remove the excess water in the specimen. This is also known as baking. After the time has elapsed, the specimen mass was removed from the hot plate and allowed to cool to temperature of about 60^0C. At this temperature, the specimen was intermounted into a prepared glass slide by using aradite. The mounted specimen was allowed to cool to room temperature and was taken to the cutting machine for size reduction. The reduced specimen was later taken to the lapping machine through the lapping jig for final reduction i.e. thinning to the required thickness of 0.3mm (a very thin section) which is the standard thin section thickness. Once this thickness was achieved, the specimen was removed from the lapping jig and washed properly to remove excess slurry around it. After washing the specimen, it was allowed to air dry. The specimen was then covered with glass cover slips using Canada balsam. It was then washed with methylated spirit or acetone and detergents. This specimen was rinsed properly with water and allowed to air dry and then labeled accordingly and appropriately for microscopic analysis. After the sample preparation and thin section preparation, the next stage is the petrographic analysis in the laboratory to determine the amount and type of minerals present by modal composition analysis and taking photomicrographs of the slides, using the Petrological microscope.

RESULTS

Geological Mapping

The field data obtained during the geological mapping of the studied area was compiled to produce the geological map of the study area (Figure 4). Ten distinct lithologic units were mapped which includes the schistose and the massive quartzites occurring as quartzite ridge (EffonPsammite Formation) which runs norh-south, granites occurring as plutons and intrusions, calc-gneiss as intrusions within the migmatite and the quartzite while the schists and migmatites occurred as distinct rock groups. The schists, quartzitesand migmatites are interbanded with the quartzites. Otherlithologies include the gneisses, pegmatites and charnockites occupying different portions of the study area with well-defined boundaries.

Petrography of the Rocks

Thin section studies were carried out for eighteen carefully selected rock samples representing the studied area. The results revealed the dominance of some prominent minerals such as quartz, biotite, muscovite, plagioclase and microcline, orthoclase and hornblende, These minerals were studied under plane-polarized light and crossed nicols. Their photomicrographs as well as the modal composition of the minerals are presented in slides 1-18 respectively.

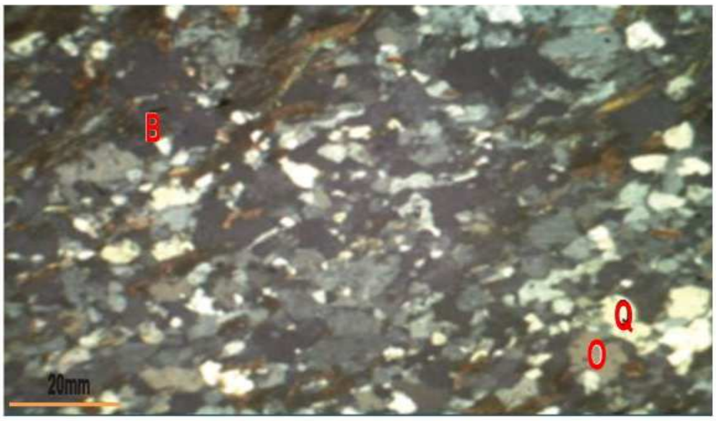

Plate 1: Photo of Micrograph of Banded Gneiss in Transmitted Light (PPL) Showing Biotite (B), Quartz (Q) and Orthoclase Feldspar (O) Magnification X10 Dpi (180)

Table 1

Banded Gneiss (Slide 1) Okemesi	
Minerals	**Composition (%)**
Quartz	59.50
Biotite	38.84
Orthoclase	1.66
Total	**100**
Texture: Medium to Coarse Grained	

Plate 2: Photo Micrograph of Banded-Gneiss in Transmitted Light (PPL) Showing Quartz (Q), Biotite (B), and Orthoclase Feldspar (Pl) Magnification X10 Dpi (180)

Table 2

Banded-Gneiss (Slide 2) Ipoti	
Minerals	**Composition (%)**
Quartz	53
Biotite	25
Orthoclase feldspar	20
Opaque	2
Total	**100**
Texture: Fine to Coarse Grained	

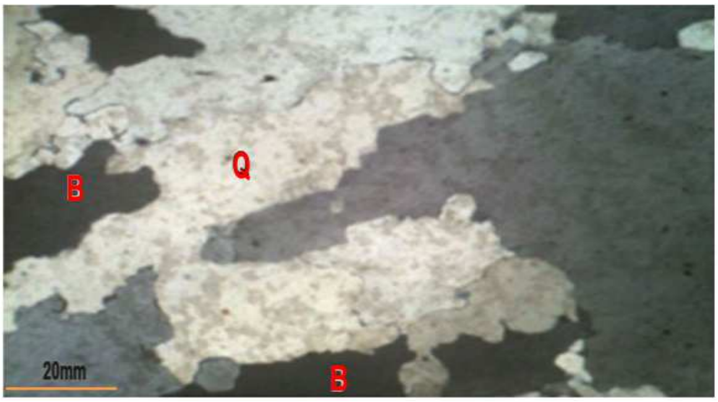

Plate 3: Photo Micrograph of Quartzite in Transmitted Light (PPL) Showing Quartz (Q) and Biotite (B), Magnification X10 Dpi (180)

Table 3

Quartzite (Slide 3) Okemesi	
Minerals	**Composition (%)**
Quartz	93
Biotite	7
Total	**100**
Texture: Fine To Coarse Grained	

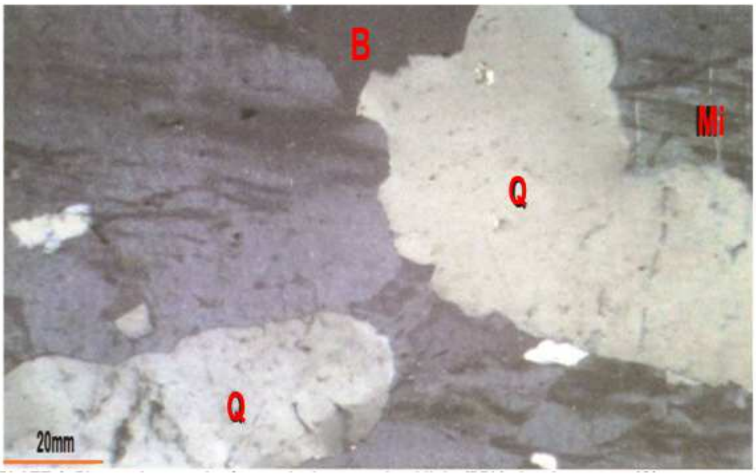

Plate 4: Photo Micrograph of Quartzite in Transmitted Light (PPL) Showing Quartz (Q), Biotite (B), and Micrograph Feldspar (Mi) Magnification X10 Dpi (180)

Table 4

Quartzite (Slide 4) Okemesi	
Minerals	**Composition (%)**
Quartz	40
Microcline	55
Biotite	5
Total	**100**
Texture: Coarse Grained	

Plate 5: Photo Micrograph of Schistose-Quarzite in Transmitted Light (PPL) Showing Quartz (Q), Biotite (B), Amphibole (Amp) and Orthoclase Feldspar (PI) Magnification X10 Dpi (180)

Table 5

Shistose Quartzite (Slide 5) Okemesi	
Minerals	**Composition (%)**
Quartz	11
Biotite	22
Amphibole	26
Orthoclase feldspar	38
Opaque	3
Total	**100**
Texture: Schistose	

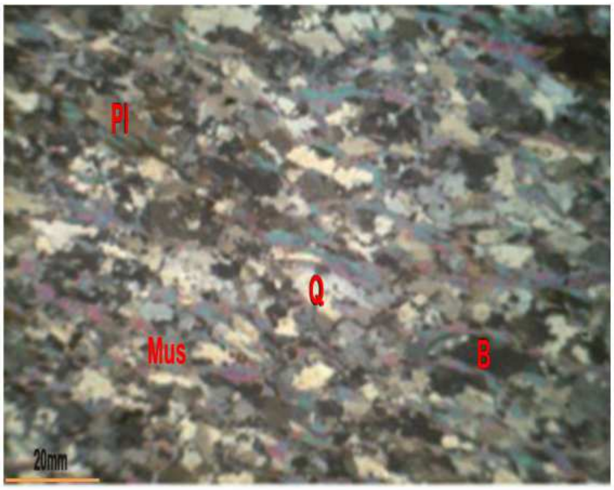

Plate 6: Photo Micrograph of Biotite-Gneiss in Transmitted Light (PPL) Showing Quartz (Q) , Biotite (B), Muscovite (Mus) and Plagioclase Feldspar (PI) Magnification X10 Dpi (180)

Table 6

Biotite Gneiss (Slide 6) Ipoti	
Minerals	**Composition (%)**
Muscovite	30
Quartz	21.7
Biotite	25.3

Plagioclase	23
Total	**100**
Texture: Fine to Medium Grained	

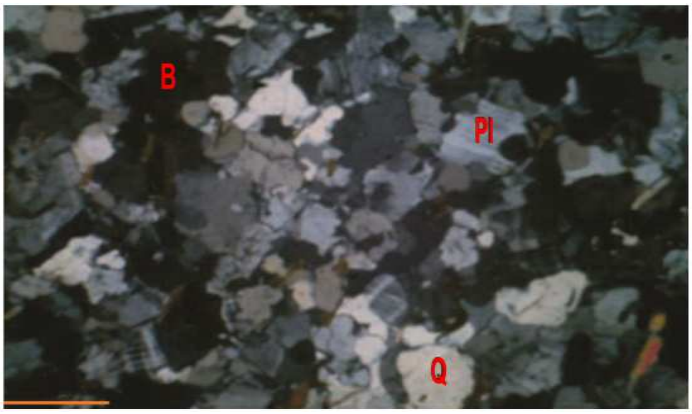

Plate 7: Photo Micrograph of Granite-Gneiss in Transmitted Light (PPL) Showing Quartz (Q), Biotite (B), and Plagioclase Feldspar (PI) Magnification X10 Dpi (180)

Table 7

Granite-Gneiss (Slide 7) Okemesi	
Minerals	**Composition (%)**
Quartz	27
Biotite	33
Plagioclase feldspar	40
TOTAL	**100**
Texture: : Medium to Coarse Grained	

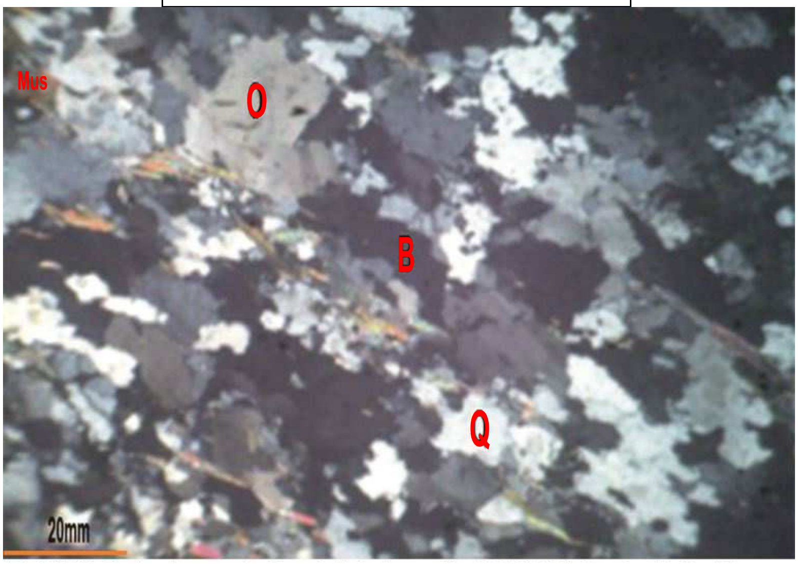

Plate 8: Photo Micrograph of Granite-Gneiss in Transmitted Light (PPL) Showing Quartz (Q), Biotite (B), Amphibole (Mus) and Orthoclase Feldspar (PI) Magnification X10 Dpi (180)

Table 8

Granite-Gneiss (Slide 8) EPE	
Minerals	**Composition (%)**
Quartz	30
Orthoclase	26

Biotite	38
Muscovite	6
Total	**100**
Texture: Medium to Coarse Grained	

Plate 9: Photo Micrograph of Biotite Schist in Transmitted Light (PPL) Showing Biotite (Q), Biotite (B), and Quartz (Q) Magnification X10 Dpi (180)

Table 9

Biotite Schist (Slide 9) Arapate	
Minerals	**Composition (%)**
Quartz	20.49
Biotite	79.51
Total	**100**
Texture: Fine to Medium Grained	

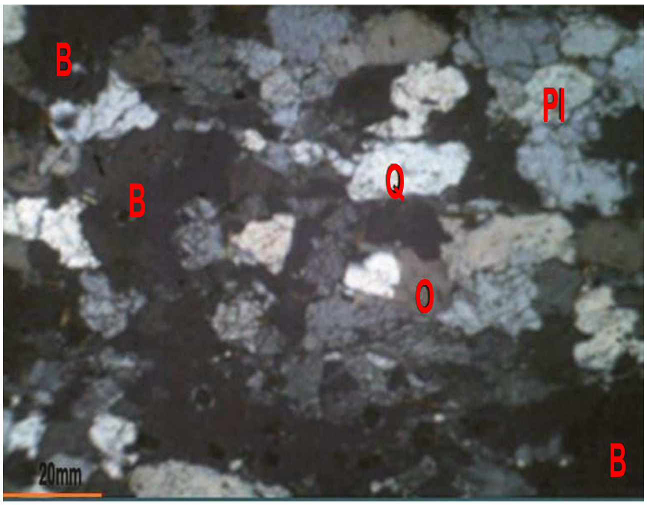

Plate 10: Photo Micrograph of Schistose-Quarth- Biotite Schist in Transmitted (PPL) Showing Biotite (B), Quartz (Q), Plagioclase Feldspar (pi) and Orthoclase Feldspar (O). Mangnification x10. Dpi (180)

Table 10

Quartz-Biotite-Schist (Slide 10) Oko-Esinkin	
Minerals	**Composition (%)**
Quartz	32.33

Biotite	43.67
Plagioclase feldspar	5.30
Orthoclase feldspar	18.7
Total	**100**
Texture: medium to coarse grained	

Plate 11: Photo Micrograph of Pegmatite In Transmitted Light (PPL) Showing Quartz (Q), Microcline Feldspar (Mi) and Orthoclase Feldspar (O). Mangnification X10. Dpi (180)

Table 11

Pegmatite (Slide 11) Ijero	
Minerals	**Composition (%)**
Orthoclase	10
Albite	11
Quartz	72
Microcline	7
Total	**100**
Texture: coarse-grained	

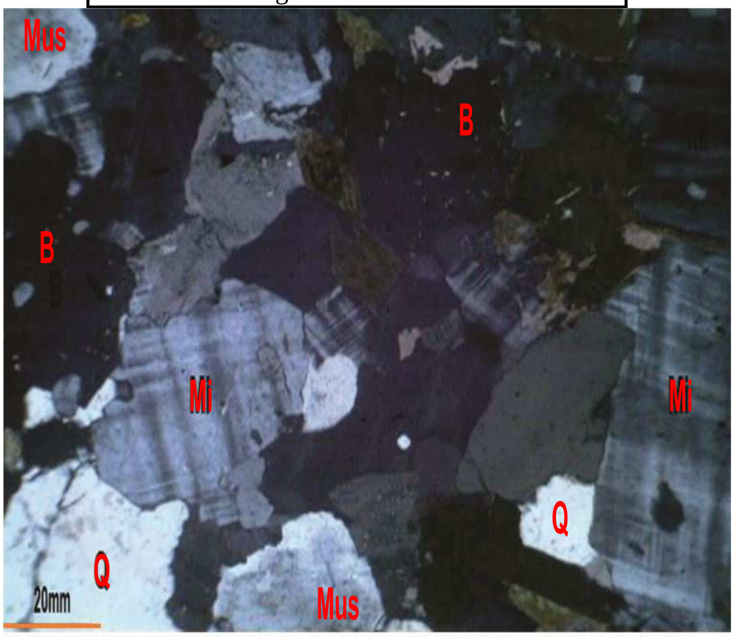

Plate 12: Photo Micrograph of Pegmatite in Transmitted Light (PPL) Showing, Biotite (B), Quartz (Q) and microcline Feldspar (Mi) Magnification X10 Dpi (180)

Table 12

Pegmatite (Slide 12) Ikoro	
Minerals	**Composition (%)**
Microcline	32
Biotite	22
Muscovite	18
Quartz	28
Total	**100**
Texture: coarse-grained	

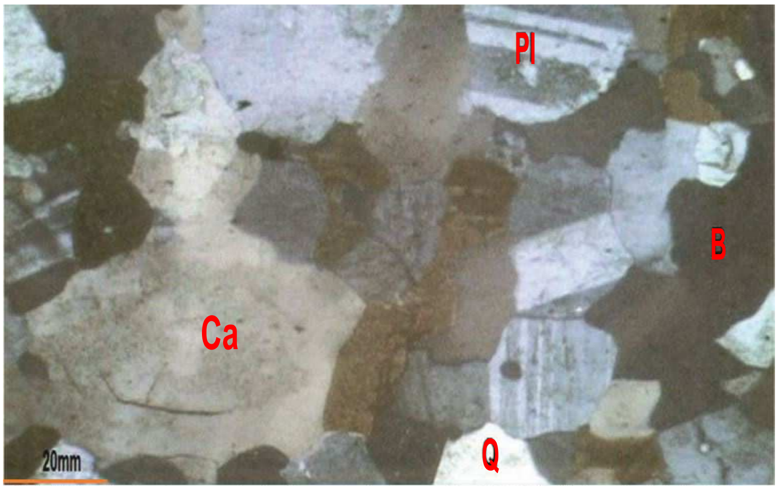

Plate 13: Photo Micrograph of calc- gneiss in Transmitted Light (PPL) Showing Quartz (Q), Biotite (B), Plagioclase Feldspar (pi) and calcite (Ca) Magnification X10 Dpi (180)

Table 13

Calc-Gneiss (Slide 13) Ikoro	
Minerals	**Composition (%)**
Calcite	65.42
Biotite	13.58
Quartz	11
Plagioclase	10
Total	**100**
Texture: Sugary	

Plate 14: Photo Micrograph of porphyritic granite in Transmitted Light (PPL) Showing Biotite (B), Quartz (Q) microcline Feldspar (Mi) and hornblende (H)Magnification X10 Dpi (180)

Table 14

Porphyritic-Granite (Slide 14) Idao	
Minerals	**Composition (%)**
Microcline	27
Biotite	42
Hornblende	6
Quartz	25
Total	**100**
Texture: Porphyritic	

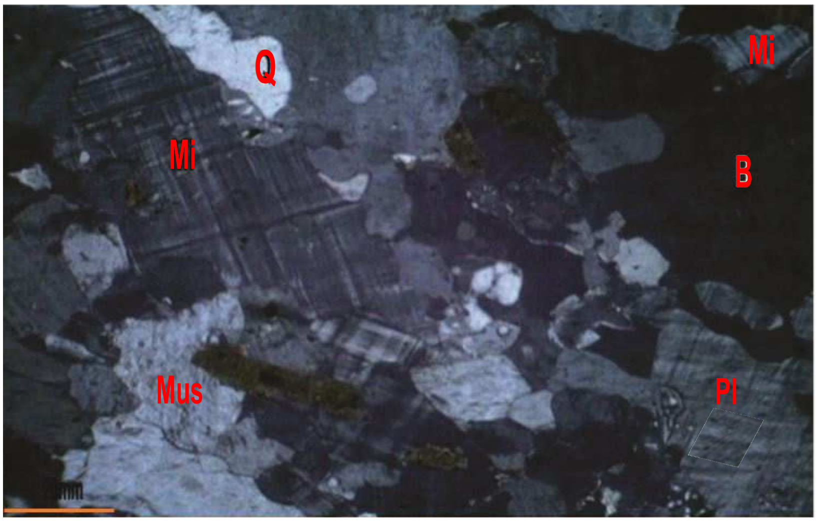

Plate 15: Photo Micrograph of porphyritic granite in Transmitted Light (PPL) Showing Quartz (Q), Biotite (B), muscovite (Mus) and microcline Feldspar (Mi) Magnification X10 Dpi (180)

Table 15

Porphyritic Granite (Slide 15) Ara	
Minerals	**Composition (%)**
Microcline	24
Quartz	21

Biotite	27
Plagioclase	19
Muscovite	9
Total	**100**
Texture: Porphyritic	

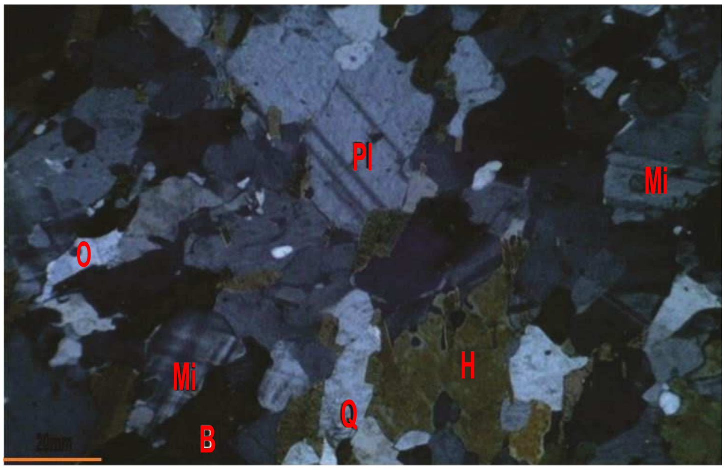

Plate 16: Photo Micrograph of granite in Transmitted Light (PPL) Showing Quartz (Q), Biotite (B), Orthoclase Feldspar (O), microcline (Mi) and Plagioclase Feldspar (pi)(PI) Magnification X10 Dpi (180)

Table 16

Granite (Slide 16) of ale	
Minerals	**Composition (%)**
Biotite	41
Quartz	10
Plagioclase	8
Orthoclase	6
Hornblende	14
Microcline	21
Total	**100**
Texture: Porphyritic	

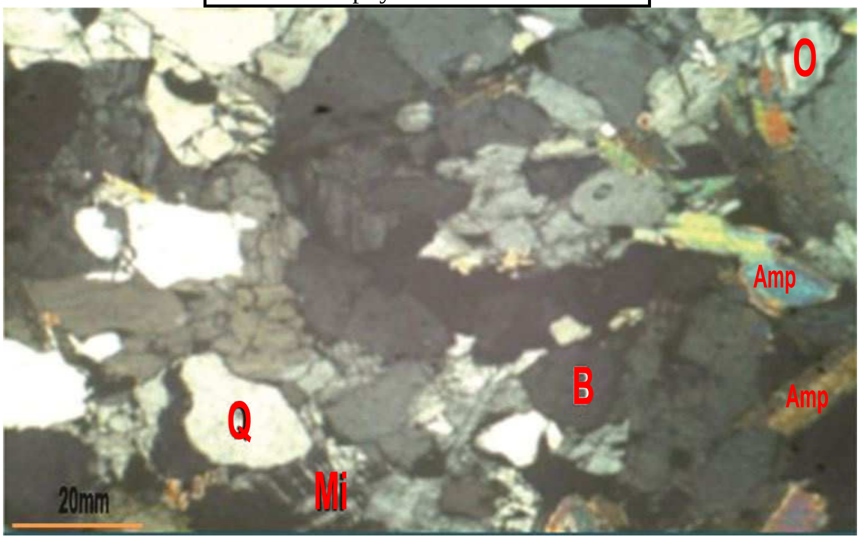

Plate 17: Photo Micrograph of granite in Transmitted Light (PPL) Showing Quartz (Q), Biotite (B), Amphibole (Amp), microcline (Mi) and Orthoclase Feldspar (O) Magnification X10 Dpi (180)

Table 17

Granite (slide 17) IJERO	
Minerals	**Composition (%)**
Quartz	21
Biotite	45
Amphibole	11
Orthoclase feldspar	9
Microcline	14
TOTAL	**100**
Texture: Coarse Grained	

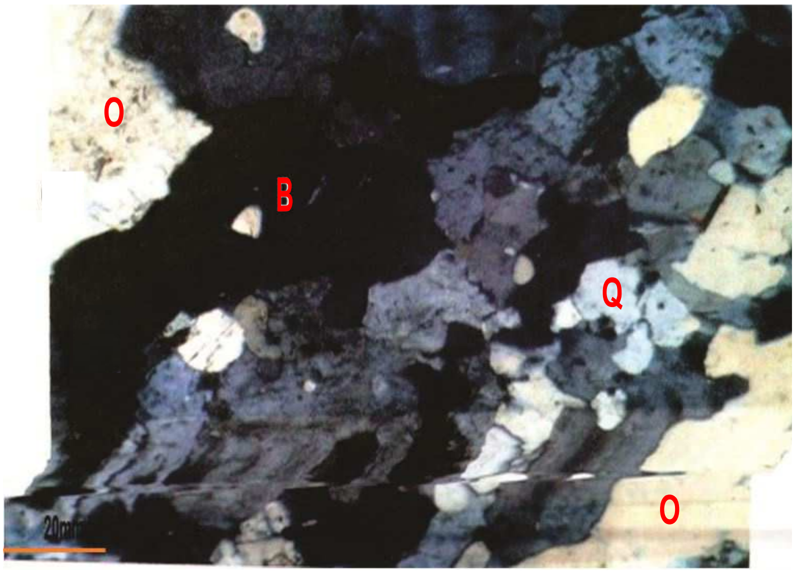

Plate 18: Photo Micrograph of migmatite gneiss in Transmitted Light (PPL) Showing Quartz (Q), Biotite (B), and Orthoclase Feldspar (O) Magnification X10 Dpi (180)

Table 18

Migmatite Gneiss (Slide 18) IJERO	
Minerals	**Composition (%)**
Quartz	18.76
Orthoclase	29
Biotite	50
Opaque	2.24
TOTAL	**100**
Texture: medium to coarse grained	

Petro Graphic Analysis of Minerals in the Slides

These minerals were detected in the slides and studied under plane-polarized light and crossed nicols, their optical characters in the slides are discussed below

Quartz

Quartz in all the thin sections account for about 30% of the total mineral present as viewed under crossed nicol. It partially greyish to white colour, and has wavy extinction. Its crystal can be described as subhedral and sometimes euhedral crystals with well developed crystal faces. The extinction angle is symmetrical with respect to crystal angle and it has tight refraction than orthoclase and microcline.

Biotite

Generally, in all the slides (1-18) viewed under Research Petrological Microscope, the percentage of biotite is about 20% of the total mineral present in the thin sections.It is dark brown in colour, highly pleochroic (changing from dark brown to light brown in colour). It is subhedral, having cleavage in one direction and of high relief. The longer axes of the biotites are aligned in a preferred orientation direction which shows foliation trend of the rock under plane polarized light. They are usually overprinted or super imposed on the muscovite minerals with yellowish brown to black colour when viewed under polarized light. Biotite has some inclusions of some accessory minerals like apatite, zircon, rutile and magnetite.

Muscovite

When muscovite is observed under Petrological microscope between crossed nicols, the interference colours are pure. However, second and third order tints of green and red crystals of muscovite were seen. They belong to the white mica which are grouped as felsic minerals. The muscovite crystals are porphyroblastic in nature, while the extinction angles of the crystals are parallel to the cleavage direction.

Plagioclase Feldspar

Plagioclase feldspars account for about 48% of the total mineral present and is partially greyish and light grey in colour and exhibits albitetwiningwith an extinction angle of about 16^0. They are generally distinguished from the other feldspars by higher refraction, the plagioclase crystals are strongly pleochroic

Hornblende

Hornblende constitutes one of the essential minerals found in granites. It is very common in Okeoro and Temidire granites. It is a mineral very difficult to distinguish from biotite unless the stage is rotated. Hornblende will remain unchanged from its brownish colour whereas, biotite exhibits variation in colour (pleochroic). Hornblende has a small extinction angle usually between 12^0- 25^0. The crystals of the minerals are usually overprinted on muscovite flakes thus; the subhedral crystal of hornblende has some elongated prism with two good cleavages

Orthoclase and Microcline Feldspar

Orthoclase feldspar occurs slightly in all the thin sections. The distinguishing factor from other feldspars is its carlsbard twinning, while microcline feldspar is also common in all the thin sections and exhibit perthite (cross-hatch) twinning under crossed nicol. It has greyish colour. Microcline also occurs as coarse grains with average composition decreasing from Ara to Ijero.

Structural Geology

The cross-sectional map (Figure 4) of the studied area confirms folding in the studied area which is noticeable on the schistose quartzites, the type of fold in the area is an antiform. Others structural attributes of the study area include;

Folds

The folds trend in a NNE-SSW direction and they are multiple and bear imprints of different generations of folding. The most striking megascopic feature in the study area is the Okemesiantiform, a large Precambrian folded structure and the axial trace of the antiform trends in a roughly N-S direction. Other folded structures are isoclinal folds,

assymetrical and overturned assymetric folds, tight folds.

Fractures

Two categories of fractures are common in the study area which is the major and minor fractures. The major fracture is the Ifewara fault which is a curvilinear structure. The fault is likely to have resulted from transcurrent movement during the folding/tectonic episodes that occurred in the study area (Odeyemi, 1992). The minor fractures were seen on the quartzite limbs and they probably developed as a result of lateral compression of the quartzites and subsequent overthrusts during the major tectonic events in the area (Figures 5&6). On the quartzites, fractures are shorter and are dominantly in the E-W direction. Those on granites are longer and more intersected and are in the N-S and NE-SW directions. The fractures on the schists and migmatites which are in the NE-SW, NW-SE and NNS directions are longer but fewer than those on the quartzite and granites. Altogether, five sets of fractures were recognized in the rocks of the studied area. The dominant ones are the E-W fractures common on the quartzites. However, there is a positive correlation between the fractures on the granites and quartzites, because their fracture patterns are similar to some extent, but dissimilar when related to the migmatites and schists. These fractures bear relationship with mineralization as they could serve as sites of ore localization and deposition. For example, certain fractures like the NE-SW types have been suggested by Wright (1976) to have connections with oceanic fracture zones and may harbour mineralization. In other cases, favourable mineral locations may occur where fractures intersect or where they are associated with suitable geological conditions. On the basis of prominent fractures from the study area, it is believed that fracturing postdated the folding episodes in the area.

Faults

The Ifewara fault is the prominent fault in the study area. It is a fault that has both thrusted and transcurrent relationship (Boesse and Ocan, 1992; Odeyemi, 1992). The fault runs from Iwaraja to Okemesi and it is noticed on ground as the Iwarajamylonite. The fault is likely to have resulted from transcurrent movement during the folding/tectonic episodes that occurred in Okemesi area (Odeyemi*et al.*, 1995. The ground truth structural map of the eastern flank of the study area (Ayodele, 2010b) confirmed the existence of other fault apart from the ifewara fault, which is a strike-slip fault that emanated during the folding/tectonic episodes in the study area. Four of these fault zones weredetected on the Landsat^{TM} Imagery interpretation of the eastern flank indicating displacements between Esa-Oke and Okemesi, Effon-Alaaye and Itawure, Erinmo and Erinodo and lastly between Imesi-Ile and Okemesi (Ayodele, 2010b).

However, the overall picture of the structural geology of the study area revealed that it has suffered several episodes of deformation and the quartzites are mostly affected by this deformation resulting in its brittleness, friable and shattered nature (Figure 7).

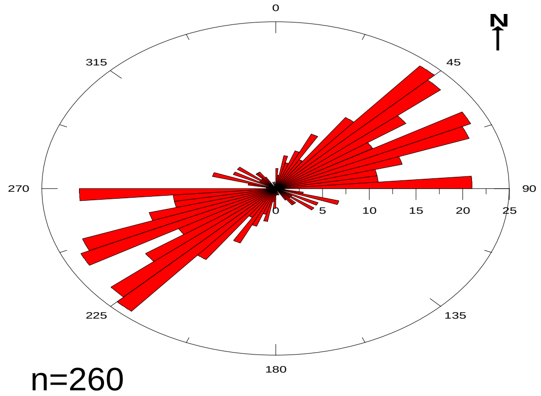

Figure 5: Rose Plots Showing the Trend of Fractures in the Quartzites, Granites, Schists, Gneisses and Migmatites

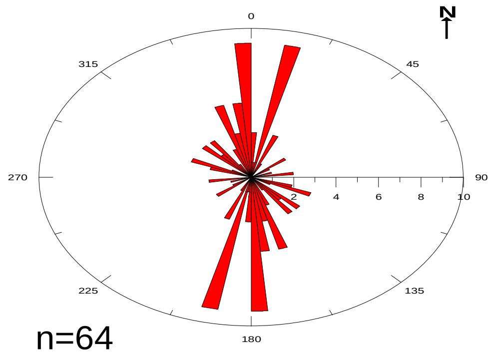

Figure 6: Rose Plot Showing Fractures Trend in the Study Area

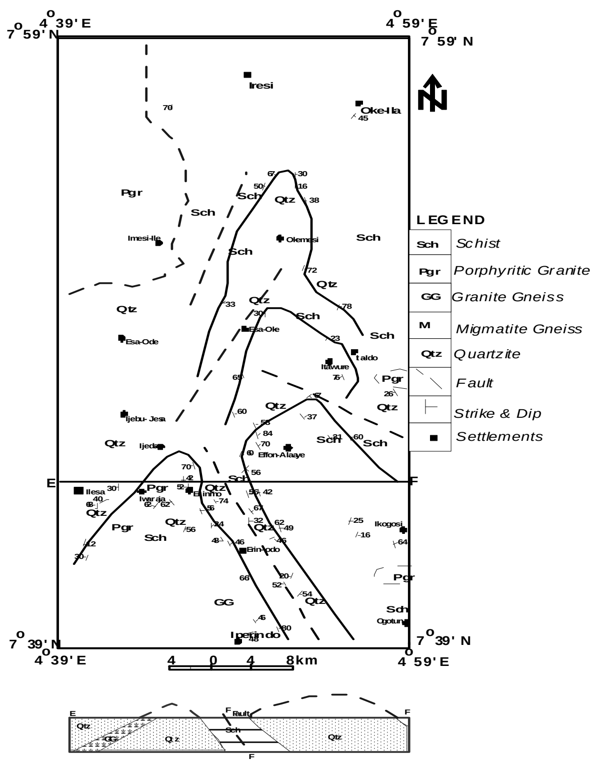

Figure 7: Structural Map of the Eastern Part of the Study Area Showing the Fault Zones (Produced by Matching Areas Dipping in the Same Direction to Generate Folded Structures as Part of Field Checks. Ayodele, 2010)

DISCUSSIONS

The study area lies within the Precambrian basement complex of southwestern which is underlain by rocks ranging from Precambrian to Paleozoic. The study area has also undergone many cycles of deformation where the geological and structural features have been completely wiped out by the deformational events that has pervaded the study area in the geologic past.The geological mapping revealed the dispositions of the various rock units in the area such as the migmatites which are the oldest rocks in the study area upon which other rocks such as granites, calc gneisses and mica-schists intruded. The massive and schistose quartzites, although of the same rock units do not exist together in the area, they are interbanded with the gneisses and migmatites or occur as distinct rock units with massive topography.. The strike values of the quartzites (schistose and massive) range from 024^0-046^0in some places. Also, the rocks dip in the western direction, with values such as 40^0W - 80^0W in some areas of study,while in other areas it dips in the eastern direction with dip values ranging between 72^0E - 80^0E respectively. The high dip values could be attributed to several episodes of deformation that characterize the rocks in the area which is manifested in the brittle nature of the quartzites that display several joints and fracture sets which also control the drainage pattern in the area. Also the attitudes of the rocks measured at foliation planes revealed that some foliations are flat lying with shallow dips indicating nappe structure and others are horizontal indicating major displacements. The dip values of some rocks are as low as 32^0 suggesting an evidence of thrusting. AlsoThe petrographic studies of eighteen rock samples selected from the different localities within the study area were carried out. The average modal % compositions of each mineral in the different slides have been presented in addition with the photomicrographs of the different thin sections of the rocks. The petrographic investigation showed that a distinct boundary can be drawn between banded gneiss, pegmatite, quartzite, biotite-schist, biotite-gneiss and Quartz-biotite schist in the study area based on the texture and mineralogical composition. The texture of pegmatite is coarse grained, which is indicative of plutonism. It cooled very slowly close to the earth surface which resulted in its texture.

Petrographic studies revealed that quartz has the highest quantity in all the sections. The quartzites found in the study area are of different varieties which are cloudy white, milky quartzites and purely white quartz found around Ajindo. Other types of quartzites include those with brown to grey variety such as smoky quartz with minerals like quartz, biotite, opaque and feldspar found around Olokuta/ Soso, Erigbe, Okeila 1 and Ilupeju area, another type includes the schistose quartzites which show foliations. Minerals present include quartz, biotite and opaque minerals such as pyrite, sulphide etc. Due to high temperature and pressure that the schistose quartzites have been subjected, the minerals were observed to be streteched under the microscope which is an indication of deformation. However, all the thin sections studied revealed that the rocks are characterized by the assemblages of quartz, biotite, muscovite, plagioclase, orthoclase, microcline and opaque minerals. It can be deduced that both the texture and mineralogical composition of the Precambrian rocks in the area vary from one rock to another which is indicative of the mode of emplacement of the rocks.For instance, remote sensing and geological evaluation of Okemesi area (Ayodele and Odeyemi, 2010a) revealed that the rocks formed in the study were emplaced by plate tectonics, which could be a product of marginal back-arc subduction process. The theory behind this assertion can be found in the work of Burke *et al.,* (1977). This is evidenced by the nature of the quartzites in the area which are not pure but are suspected to be of pelitic origin because of their friable nature.

CONCLUSIONS

The rose plots for the studied area displayed fracture azimuths and sets. The rose plots provided a unique evidence to support the deformational history of the area. The fractures also demonstrated the brittle and ductile nature of the rocks

in the area in terms of fracture lengths and densities. The fracture patterns differ from one lithology to the other. For instance, the E-W fractures are common with the quartzites, while the N-S, NE-SW ones are synonymous with the granites and are longer and interconnected while the schists, gneisses and migmatites have paucity of fractures because of their ductile nature. They have shorter fractures and are mostly in the NNS, NW-SE direction. Remote sensing studies carried out in some parts of Okemesi area also confirmed the existence of assymetric and overturned antiformal folds and other structures such as veins faults and joints (Ayodele and Odeyemi, 2010a). The major fault (Ifewara fault) is likely to have resulted from transcurrent movements during the folding/tectonic episodes that occurred in the area (Odeyemi,1993), while the minor fractures noticed on the quartzite limbs probably developed as a result of lateral compression of quartzites and subsequent overthrusts during the major tectonic events in the study area. Other folded structures such as tight, isoclinal and tight folds were seen and mapped on the field which is associated with the migmatite-gneisses and schists.The general strike direction is NE-SW because several episodes of deformation have pervaded the basement complex in the geologic past, which had resulted in the re-orientation of the N-S trend of most outcrops (Oluyide, 1988; Okonkwo, 1992). The range of metamorphism from field studies show a low to high grade because the quartz content of the quartzites increases from one location to the other while minerals such as muscovite, feldspar and quartz are prevalent in most outcrops by inspection.

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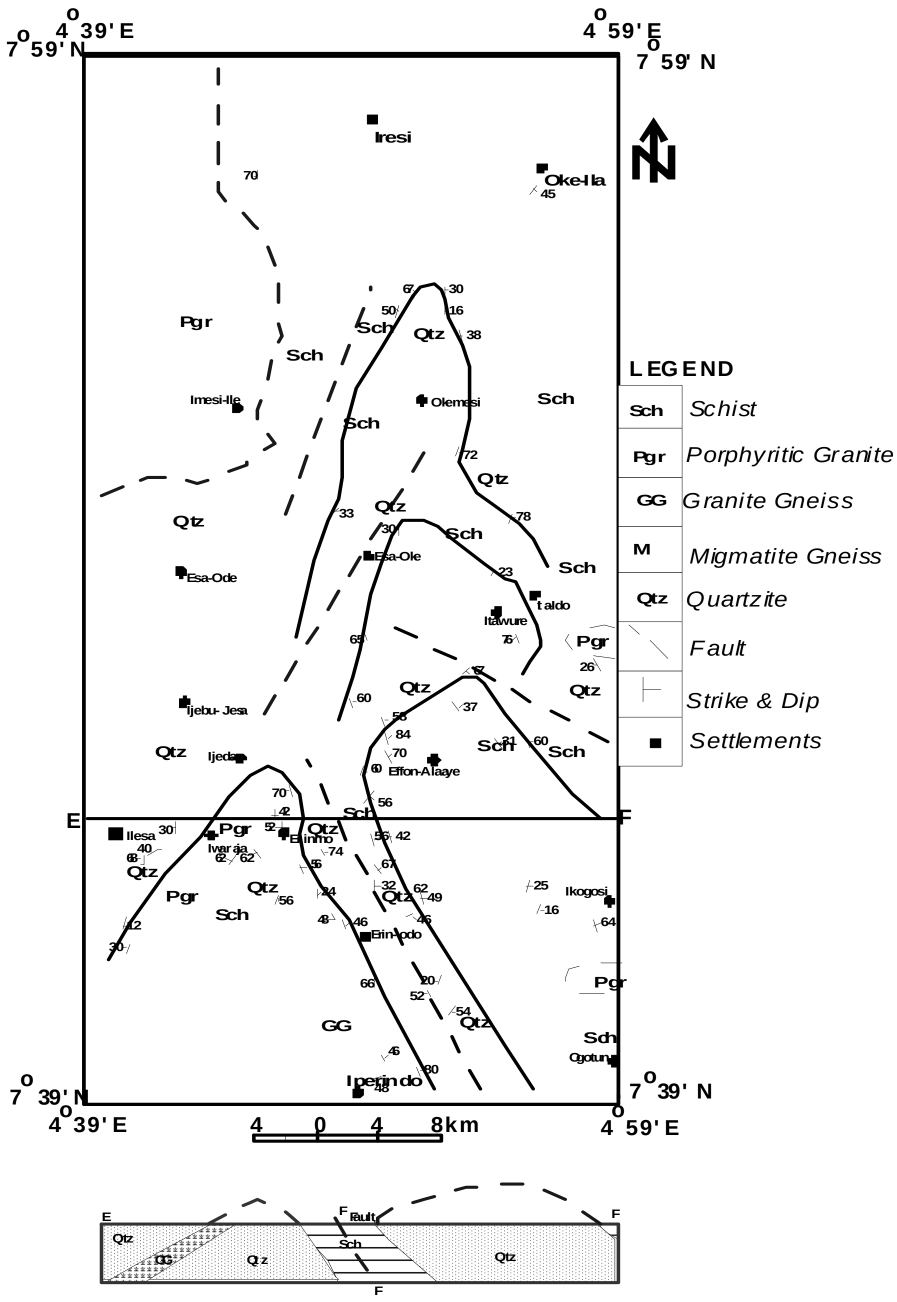

Figure 8: Structural Map of the Study Area (Produced by Matching Areas Dipping in the Same Direction to Generate Folded Structures as Part of Checks)